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4th QTR

LANDSAT 2 PROJECT NO. 2896D

4TH QUARTERLY PROGRESS REPORT

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(E77-10097) WATER UTILIZATION, EVAPOTRANSPIRATION AND SOIL MOISTURE MONITORING IN THE SOUTH EAST REGION OF SOUTH AUSTRALIA Quarterly Progress Report (Bureau of Mineral Resources) 5 p HC A02/MF A01

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I INTRODUCTION

Title Water Utilization, Evapotranspiration and Soil Moisture Monitoring in the South East Region of South Australia.

Assigned Investigation No.: 2896D

Author's Name: K.R. McCloy
K. John Shepherd
J.C. Killick

Reporting Date: Dec. 2, 1976. (FTD + 14 months)

II TECHNIQUES

1. Material Received

70 mm Format NIL

9 track, 1600 B.P.I. CCT. Frames 2342-23411 and 2359-23351 received by the last quarterly report are being used. Frame 2198-23424 of 8 Aug. 1975 was damaged in transit to Australia and has subsequently been returned to NASA. We have not yet received a replacement.

2. Status of Project

(i) Linear Classifier. The Linear Classifier developed by McCloy and mentioned in previous reports has now been used to classify Bool Lagoon at three dates, 29th November, 1972, 30th December, 1975, and 16th January, 1976, and compared with aerial photography. These results with the dune survey have been offered for presentation at the Remote Sensing of Environment symposium in April 1977. A Comprehensive Summary of the proposed paper is included.

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(ii) Detailed Landcover data has been collated into maps for the two dates, 30th December, 1975, and 16th January, 1976. These maps are being digitised to correspond to the Landsat imagery at these dates. The data will be used to ascertain the linearity of naturally occurring pasture types, for classification, and then testing the reliability of that classification. Initial work by McCloy suggests that the change in response across pasture is approximately linear, and related primarily to plant stage

of growth.

(iii) Because of the late receipt of digital data it is requested that the project be allowed to continue for another two reporting periods and that a final report be produced at that time. It is anticipated that the next three months will be involved in finishing digitisation of Landcover, and extracting initial results from this. The second reporting period would be used to classify test areas and analyse the reliability of the results.

III ACCOMPLISHMENTS

Successful operation of the improved Classifier routines.

IV SIGNIFICANT RESULTS

Nil this Quarter.

V PUBLICATIONS

COMPREHENSIVE SUMMARY ONLY

THE VECTOR CLASSIFIER

INTRODUCTION

Most digital classifier algorithms assume point classes, with a defined envelope. This paper describes the development and discusses successful applications of a linear classifier.

Conceptually, the classifier has a number of operator designated nodes or limiting surface types specified by their mean covariance arrays. These n nodes define a linear surface in m dimensional space.

This linear surface has both dimension and orientation, hence it can be considered to be a linear vector surface. Any pixel containing proportions of the various surfaces will lie on this vector, with proportions being defined by the position of the pixel with respect to the nodes.

For classifying scanner imagery, the pixel must be assumed to not lie on the surface. The algorithm uses a constraint to find the footpoint on the surface that is "closest" to the actual pixel. The closest is in geometrical terms and under certain conditions the footpoint is near, but not the actual closest point. These conditions will only allow determination of the closest point in an involved manner, which is not considered to be justified.

The separation of the pixel from this footpoint can then be tested against statistical or geometric thresholds to determine whether the pixel can be classed as belonging, or not belonging to the vector surface.

Tl. procedure determines the proportions of the various nodes represented in the pixel, so that those pixels classified as belonging to the vector can be sub-classified according to their proportions of the various surface types.

The derivation is based on independant types of surface cover similar to those used by Horwitz and Nalepka in their article "Estimating the proportions of objects within a single resolution element of a multispectral scanner", presented at the 7th Symposium in this series. To be maximally usefull, the classifier should be capable of classifying between the limits of an environmentally changing type of surface. The paper discusses a number of situations when the variations in radiance with variations in environmental condition, do display linear characteristics, and can be reliably classified with this technique.

THEORETICAL DERIVATION

The power received by a scanner from an IFOV covered by a uniform surface of radiance N_λ is given by:-

$$P_\lambda = \int_o^\Omega \int_o^{Ac} N_\lambda \eta_o t_d \, da. \, d\theta^2 \qquad + \ldots\ldots\ldots 1.$$

If the IFOV contains n surfaces of spectral radiances $N_{1\lambda}$, $N_{2\lambda}$, Nn_λ, then the power received is given by:-

$$P_\lambda = \int_o^\Omega \int_o^{Ac} N_{1\lambda} \eta_o t_d \, da \, d\theta^2 + \int_o^{\Omega^2} \int_o^{Ac} N_{2\lambda} \eta_o t_d \, da \, d\theta^2 \qquad + \ldots\ldots\ldots 2.$$

THEORETICAL DERIVATION Cont..

Now $\frac{\Omega_1}{\Omega} = \frac{\Lambda_1}{\Lambda} = a_1$, etc...and the scanner response values are linearly related to radiance and hence power received, so that;

$$R_\lambda = a_1 R1_\lambda + a_2 R2_\lambda + \ldots + a_n Rn_\lambda \qquad \ldots 3$$

R_λ is the pixel response, $R1_\lambda$ the response of surface 1, etc.

If there are m wavebands W,X,Y, ...M and n surfaces 1,2,3,...n then we would have the m equations

$$\begin{aligned} R_w &= a_1 R1_w + a_2 R2_w + \ldots + a_n Rn_w \\ R_x &= a_1 R1_x + a_2 R2_x + \ldots + a_n Rn_x \qquad \ldots 4 \\ &\vdots \\ R_m &- a_1 R1_m + a_2 R2_m + \ldots + a_n Rn_m \end{aligned}$$

Now for any pixel, not on the vector, we want the footpoint on the vector. The footpoint will be that point for which

$$a_1 + a_2 + a_3 + \ldots + a_n = 1 \qquad \ldots 5$$

Substitute this into equation 4 to give:

$$\begin{aligned} R_w - Rn_w &= a_1 (R1_n - Rn_w) + a_2 (R2_w - Rn_w) + \ldots + a_{n-1} (Rn-1_w - Rn_w) \\ R_x - Rn_x &- a_1 (R1_x - Rn_x) + a_2 (R2_x - Rn_x) + \ldots + a_{n-1} (Rn-1_x - Rn_x) \qquad \ldots 6 \\ &\vdots \\ R_m = Rn_m &- a_1 (R1_m - Rn_m) + a_2 (R2_m - Rn_m) + \ldots + a_{n-1} (Rn-1_m - Rn_m) \end{aligned}$$

and as long as $M \geq (n-1)$ then these equations can be solved for $a_1, a_2, \ldots a_{n-1}$ and by equation 5, for a_n.

$(R_w, R_x, R_y, \ldots R_m)$ are the actual pixel response values.

Generally there will be less than (M+1) nodes so that the solution needs to be done by least squares. Equation 6 can be stated in matrix notation as:

$D = 0 * U$ where U is the column vector of unknown proportions.

$$0^T * 0 * U = 0^T * D$$

Let $0^T * \overset{O}{\cancel{D}} = A$

$$\therefore U = A^{-1} * 0^T * D$$

Let $A^{-1} * 0^T = B$

$$\therefore U = B * D$$

THEORETICAL DERIVATION Cont..

Array B is constant for any vector and can be determined prior to classification, so that classification only depends upon the matrix multiplication and (n-1) subtractions to determine a_n. The footpoint response values are then determined by substituting the proportion values into equation 4.

Often the footpoint will fall outside of the domain of the nodes, in which case one or more proportions will be negative. One or more may be positive. The author decided to restrict the footpoint to within the domain of the nodes. This is done by making all negative proportions zero and dividing all new proportions by the sum of the new proportions. This approach has advantages and disadvantages, which will be discussed, the author believing that the advantages outweigh the disadvantages.

If the covariance arrays for the nodes are given as COV_1, COV_2,...COV_n, then it can be shown, by the law of propagation of error, that:

$$COV\ (I,J) = a_1^2\ COV_1\ (I,J) + a_2^2\ COV_2\ (I,J) + \ldots + a_n^2\ COV_n\ (I,J)$$

for all (I,J). This gives the covariance array of the selected footpoint, so that the likelihood of the actual pixel belonging to the vector can be tested statistically, in a variety of ways.

The statistical envelope defined in this way are parabolic surfaces on either side of the vector surface. The author believes that in many cases it is not convenient to either determine or estimate the covariance arrays and believes that testing the geometric distance between pixel and footpoint will not introduce significant errors, for a saving in classification time.

ENVIRONMENTAL SUPPORT FOR CLASSIFIER

The turbid lakes of Western Victoria display linear relationships between the response bands through the series of lakes sampled. The response values are related to turbidity levels, although not necessarily in a linear manner.

Profiles across a large swamp lagoon, Bool Lagoon, give a linear relationship between the bands, from water surfaces through to the dry reed beds.

RESULTS ACHIEVED

The classifier had been used in two studies, Bool Lagoon and classifying the Sand Dunes from coastal scrub near Lake Bonney on the South Australian Coast. Both exercises were successfull and will be reported in more detail at the symposium. The Bool Lagoon work was done at three dates, 29th November, 1972, 30th December, 1975 and 16th January, 1976.